

# DESIGNING FOR POST IRRADIATION EXAMINATIONS

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*Fuel Performance and Design*

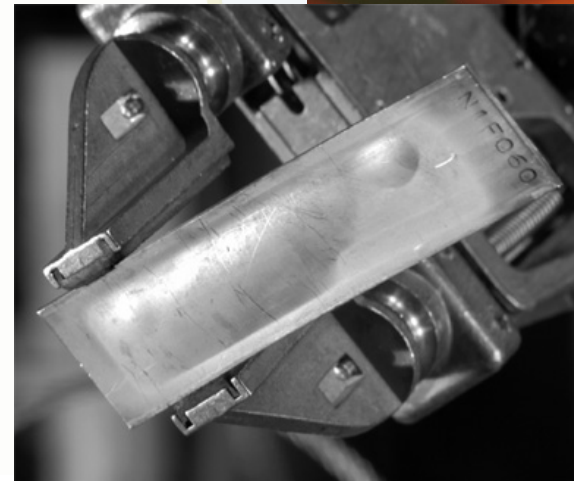
June 4, 2009

# Designing for PIE-Overview

- Introduction to experiment handling
- Requirements for fixturing
- Limitations of capabilities
- Overview of typical PIE process

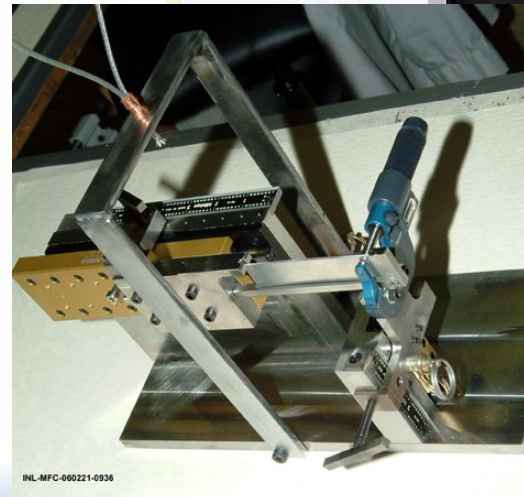
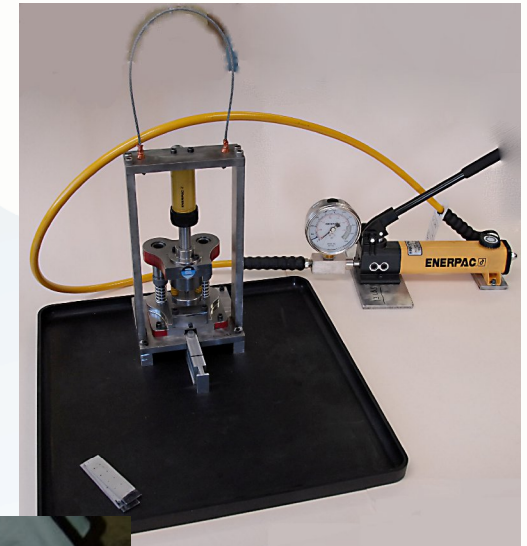
# Handling

- Three primary ways of handling samples/equipment
  - Crane (5 Tons)
  - Electro-Mechanical Manipulators (750 lbs)
  - Master/Slave Manipulators (varied from 20-50 lbs)



# Handling

- All equipment must be 'remotized' for in cell use and handling
- Equipment goes through mock-up for testing
- Equipment is typically engineered specifically for in-cell applications



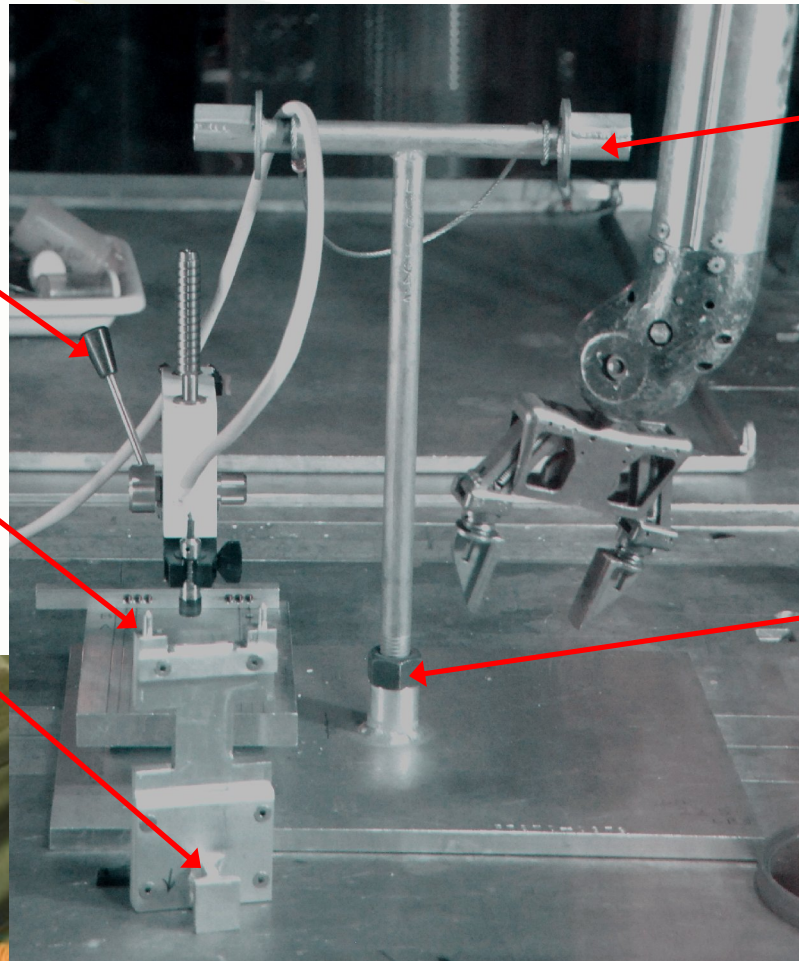


# Handling

Exaggerated  
handles

Location guides

Manipulator handles



EM "T" Handle

Oversized Bolts

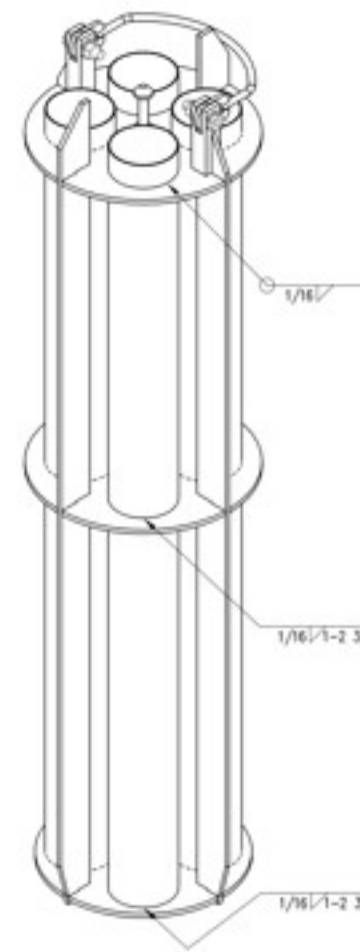
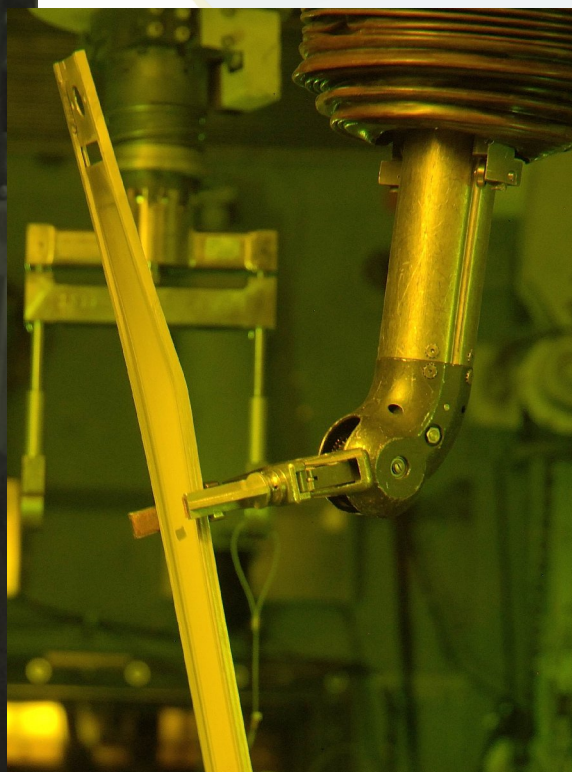
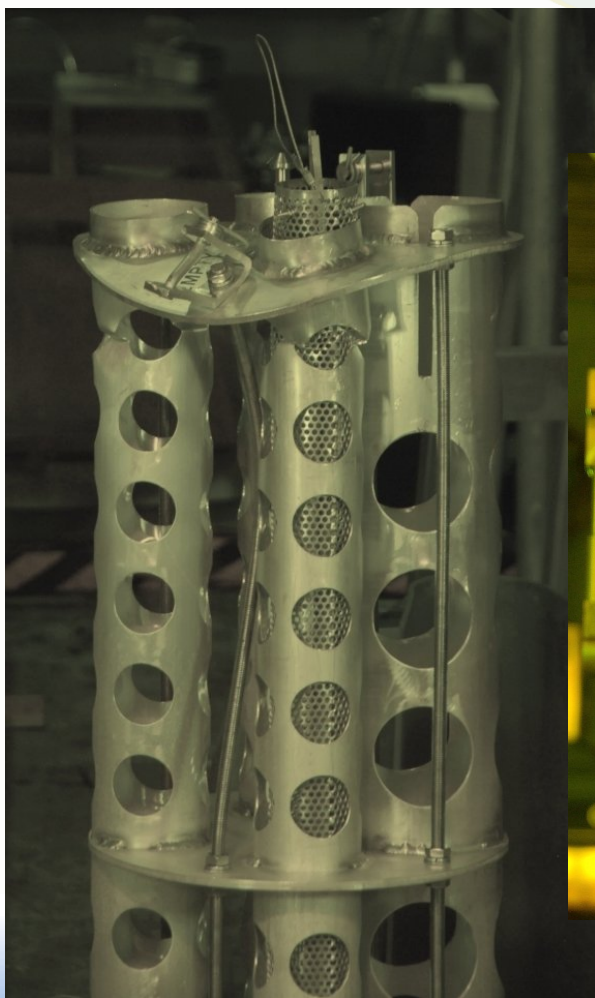
# Handling

- Irradiated items arrive in shielded casks
- Casks are handled depending on size
- Unloading done with limited visibility and specialized tools



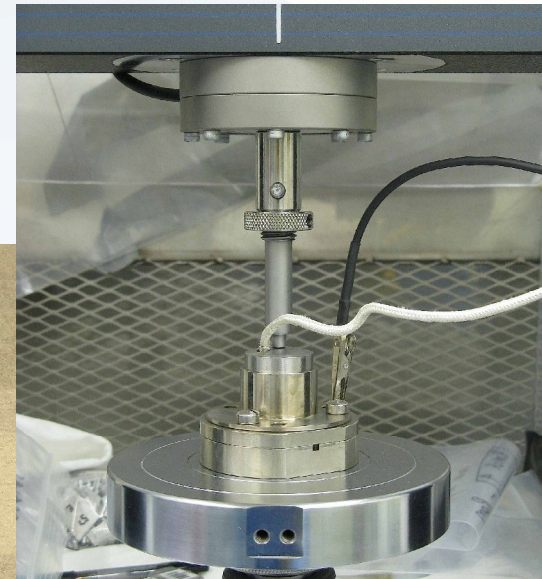
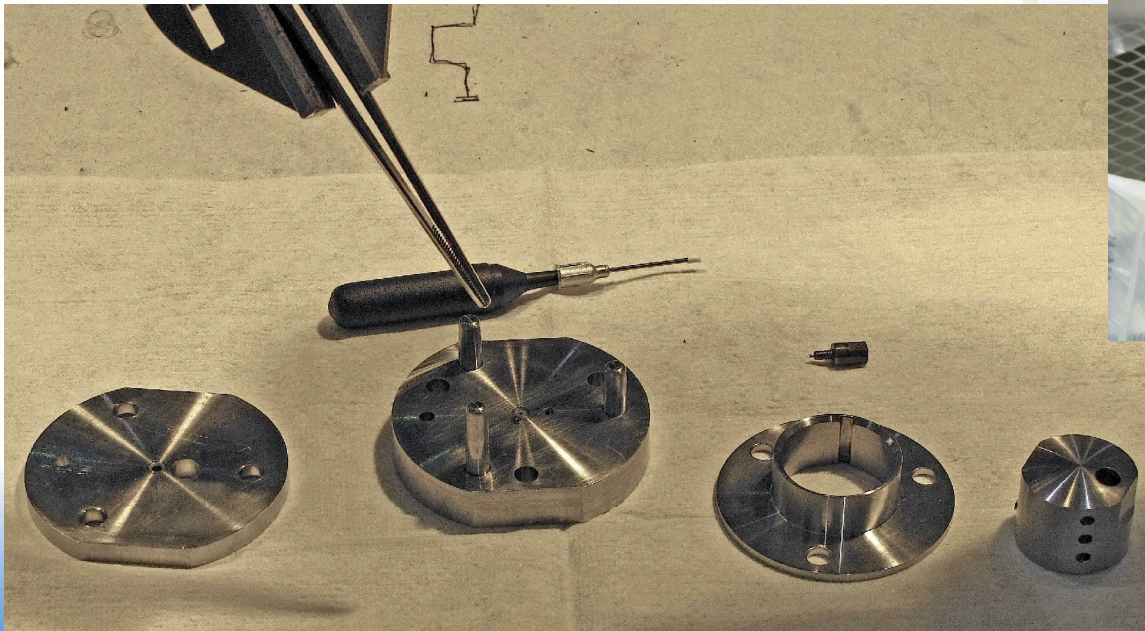


# Handling



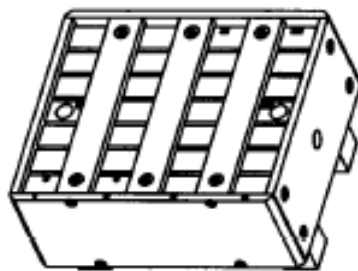
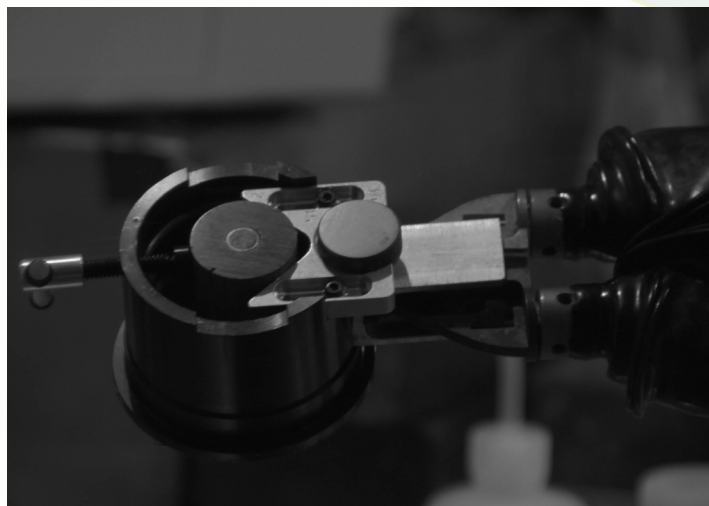
# Fixturing

- Small samples very difficult to handle, locate, and identify
- Fixturing designed for easier movement, setup, and testing





# Fixturing



# Typical Post Irradiation Exam

## Non-Destructive Exams

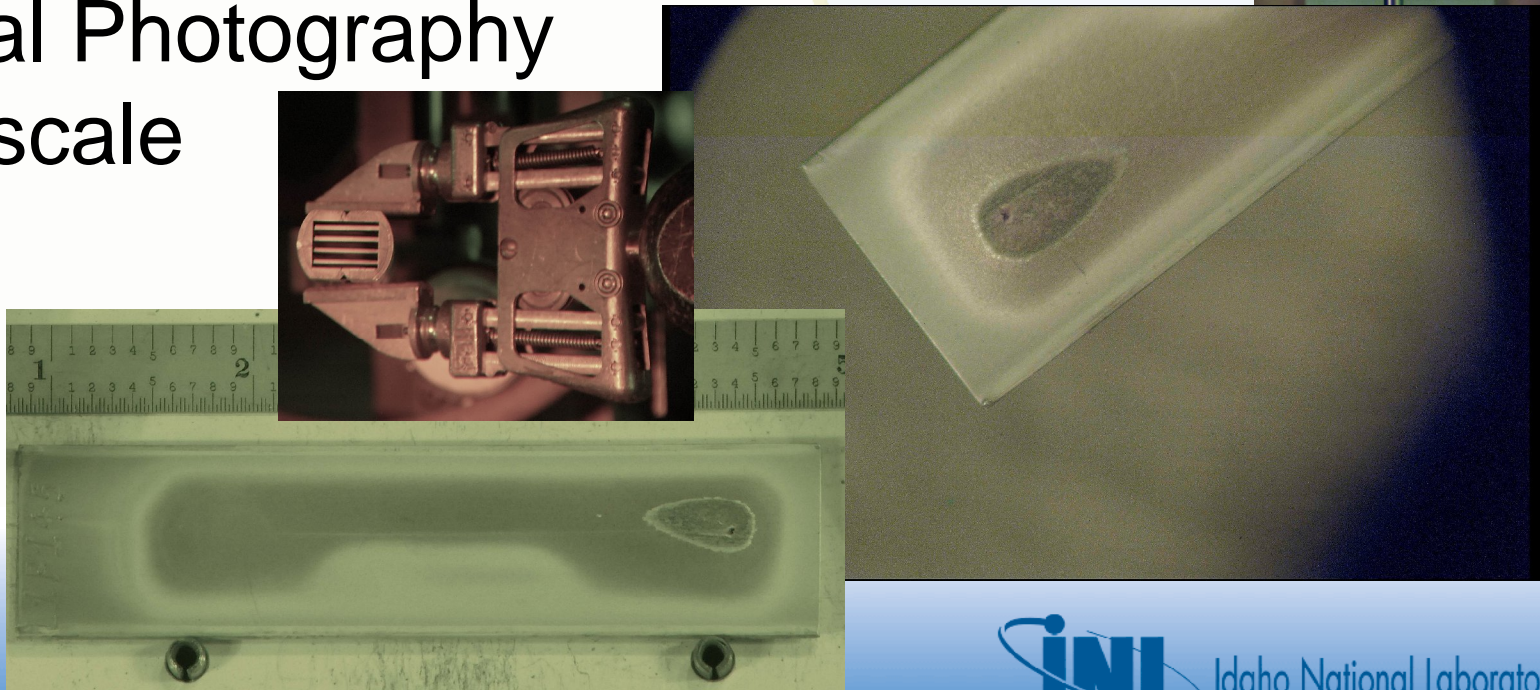
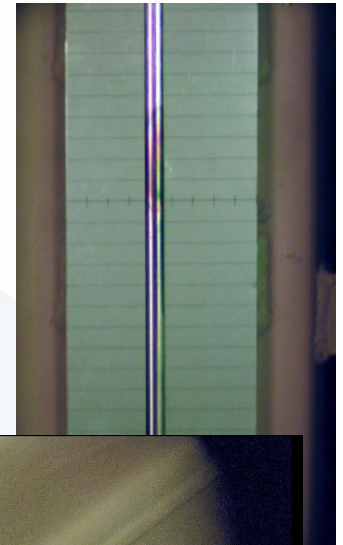
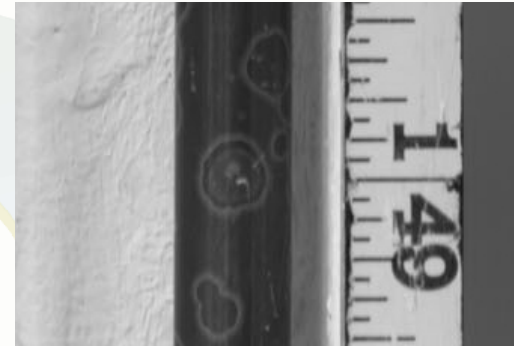
- Visual Examinations
- Neutron Radiography
- Gamma Scanning
- Dimensional Analysis
- Oxide Examination

## Destructive Exams

- Disassembly
- Burn-up Analysis
- Metallography
- Mechanical Testing
- SEM/TEM Analysis

# Visual Examinations

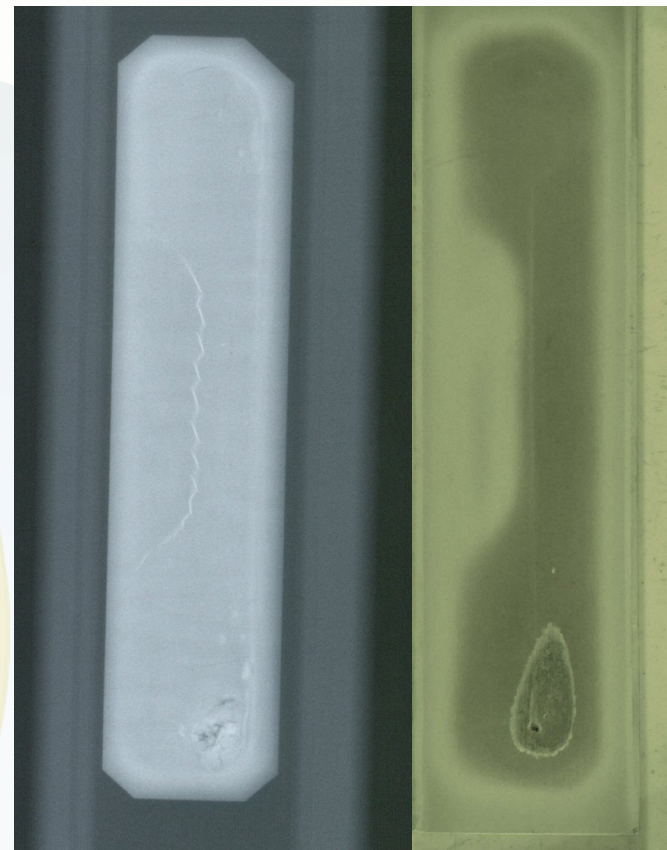
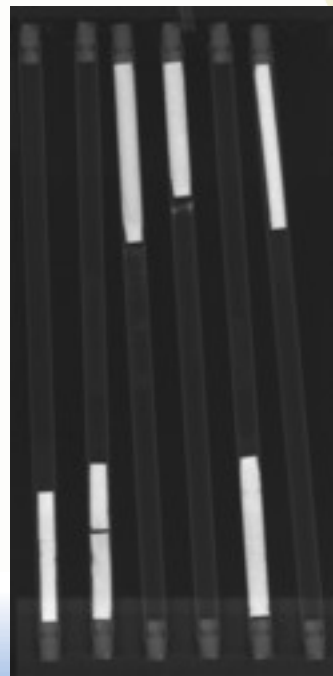
- Up to 25x magnification
- Identify defects or failures
- Digital Photography with scale





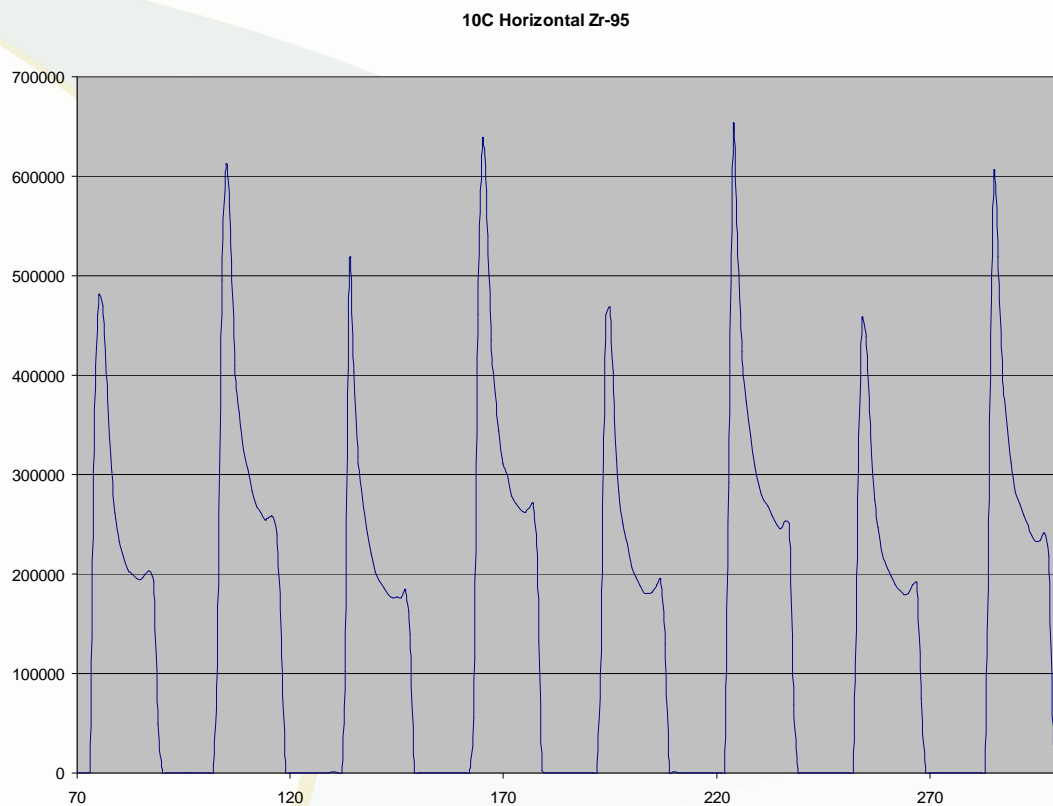
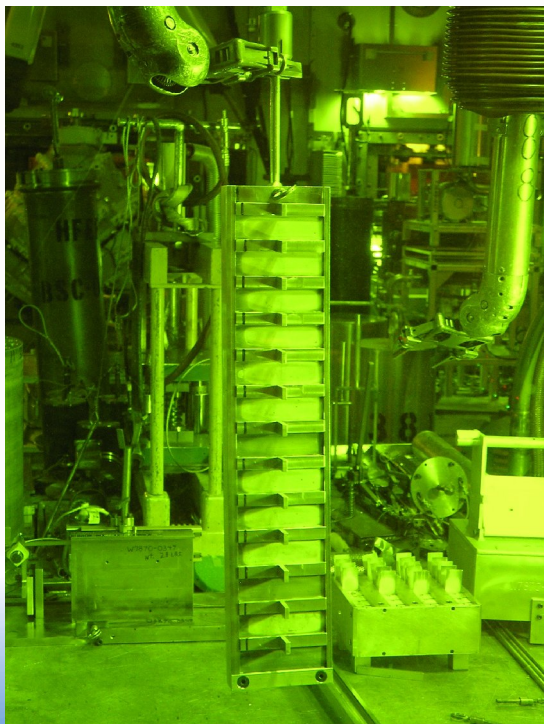
# Neutron Radiography

- Locate fuel for disassembly
- Identify cracking
- Density variations
- Hydrides in cladding



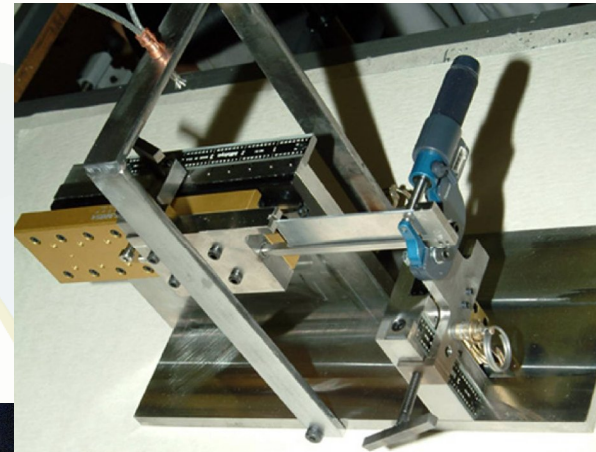
# Gamma Scanning

- Relative burn-up
- Isotopic analysis
- Variable slit width/shape (0.001" to 0.1")



# Dimensional Analysis

- Quantify swelling/growth in both the length and thickness directions
- Bow and length measurements
- New plate & rodlet remote measurement device



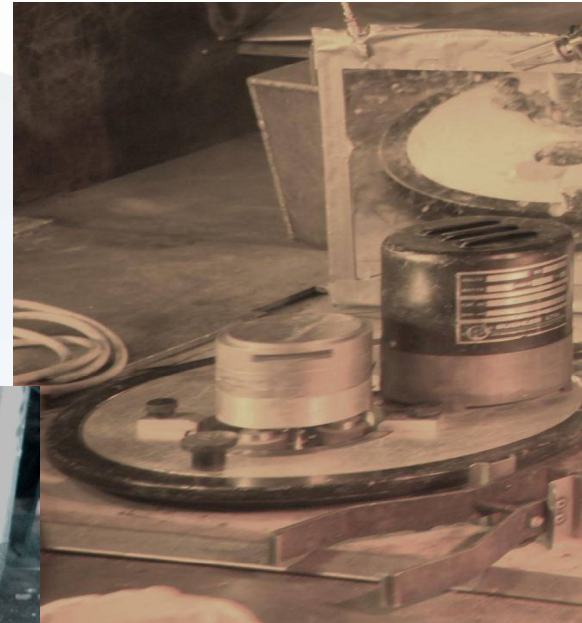
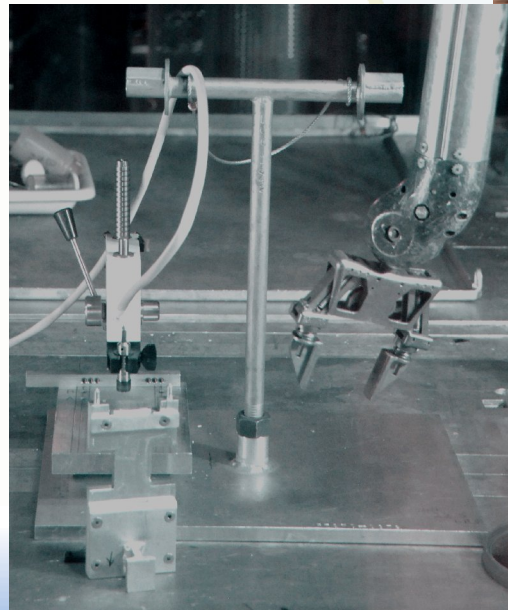
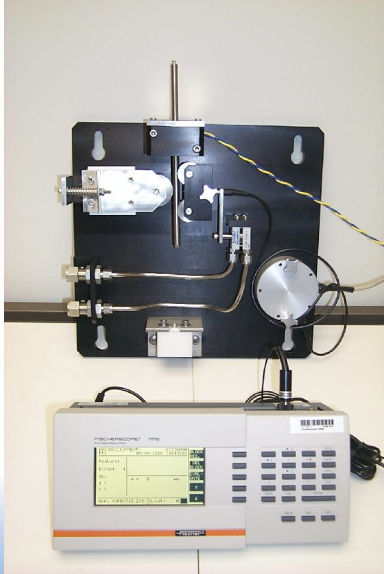
INL-MFC-000221-0936  
Mini-Plate thickness Measurement Device



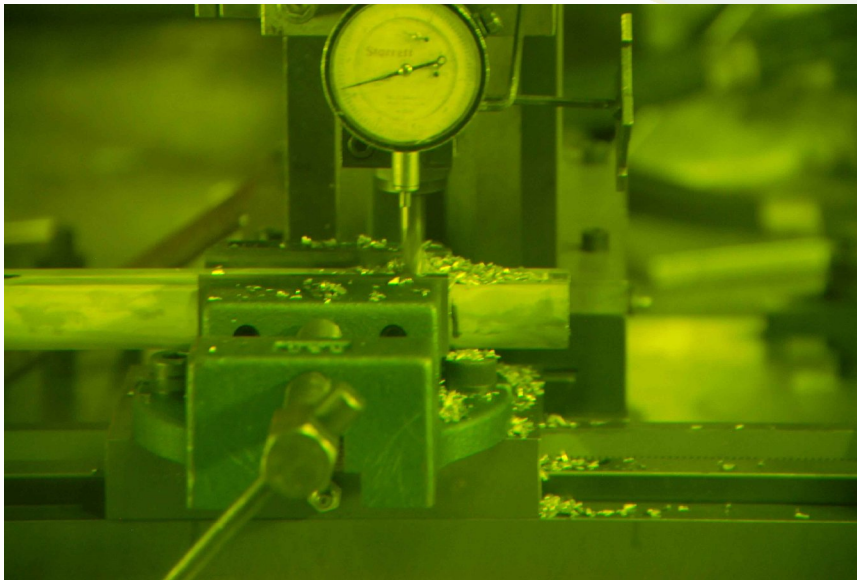


# Oxide Examination

- Eddy current method
- Individual fixturing and equipment for each experiment

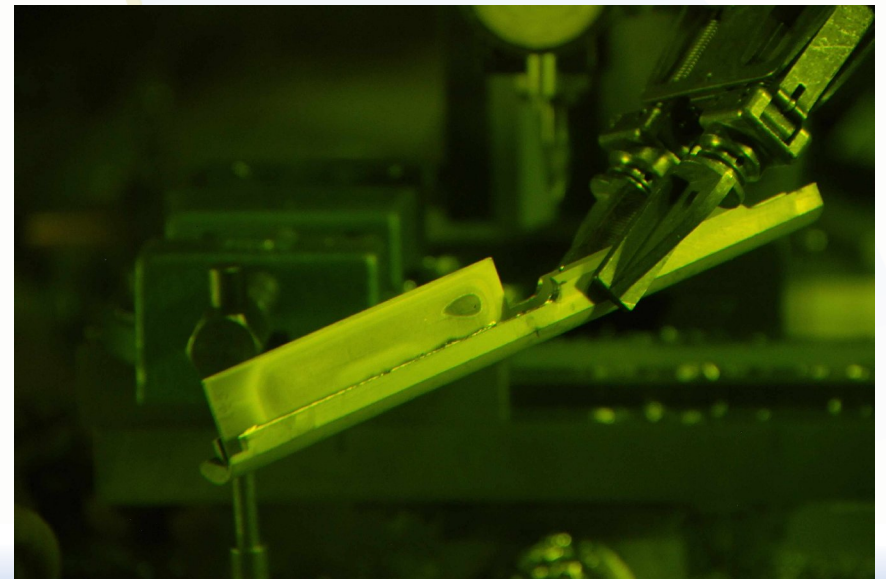


# Disassembly



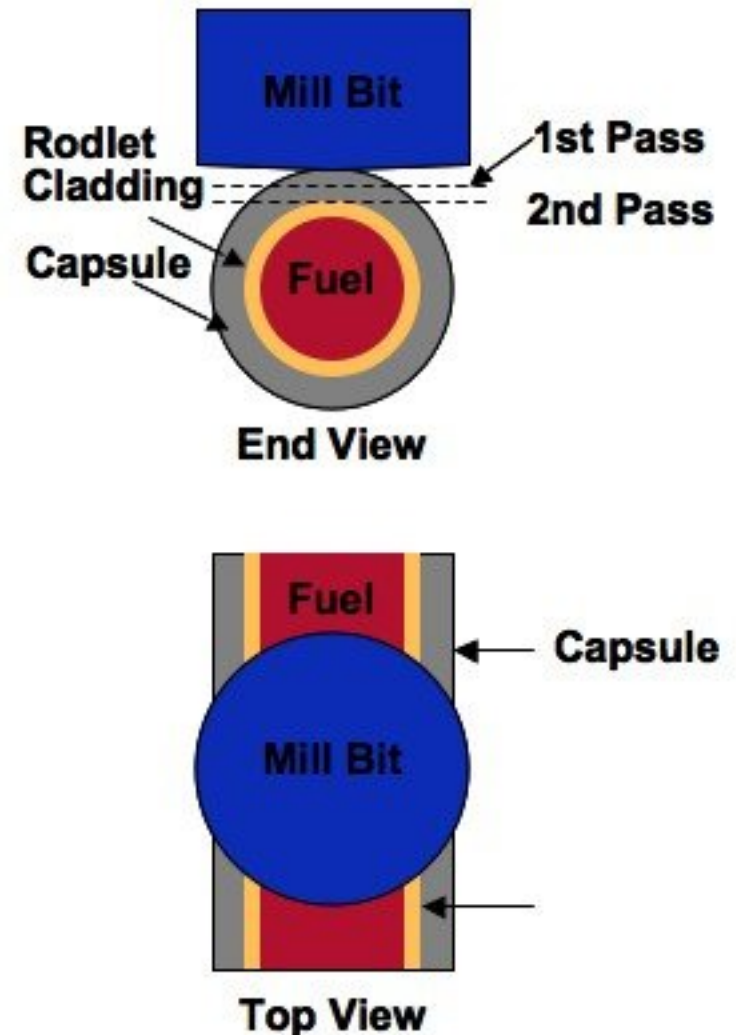
Pneumatic mill used for  
disassembling capsules

Disassembly used for AFC-1 and  
AFC-2 Irradiation Experiments, GFR  
Material Capsule Tests, LWR-1a  
Irradiation Tests, and RERTR  
Irradiation Capsules



# Disassembly

- **Axial Slitting Tool**
  - RBCB Fuel Pin Machine Defect
  - Modified Table top Mill
  - Depth control to  $< 0.0127$  mm (0.0005 in.)
  - Uni-slide for z-axis translation
- **Disassembly Operation**
  - Multiple passes at depths of 0.025 – 0.25 mm (0.001 - 0.010 in.) traverse 6 in. length of rodlet
  - Rotate rodlet 180° and repeat
  - Remove Rodlet using push rod and support fixture





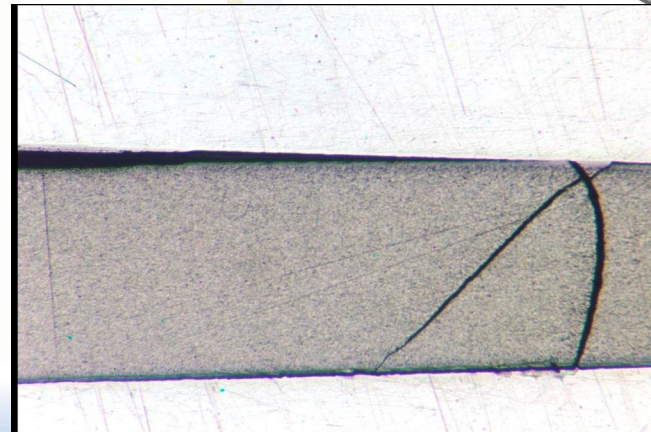
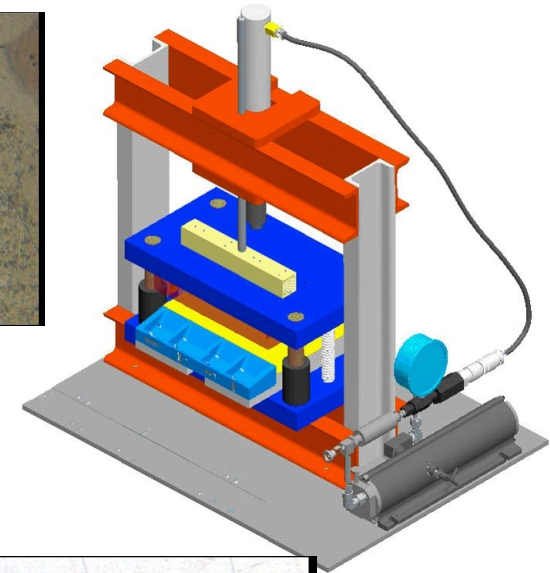
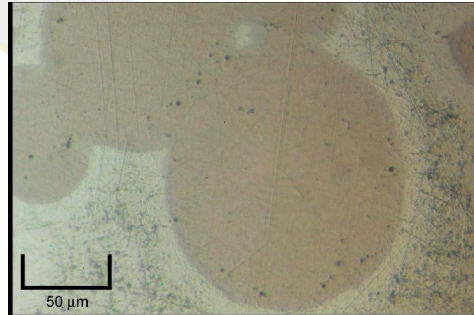
# Burn-up Analysis

- Samples prepared at HFEF and sent via pneumatic rabbit to analytical laboratory
- Samples dissolved in AL hot cell and samples taken

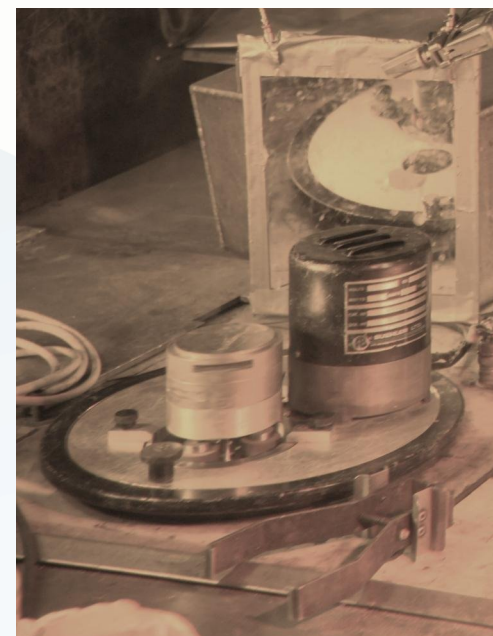
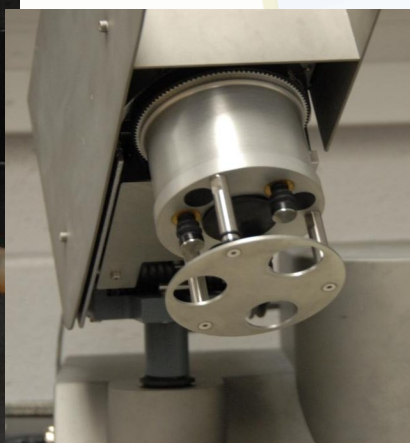
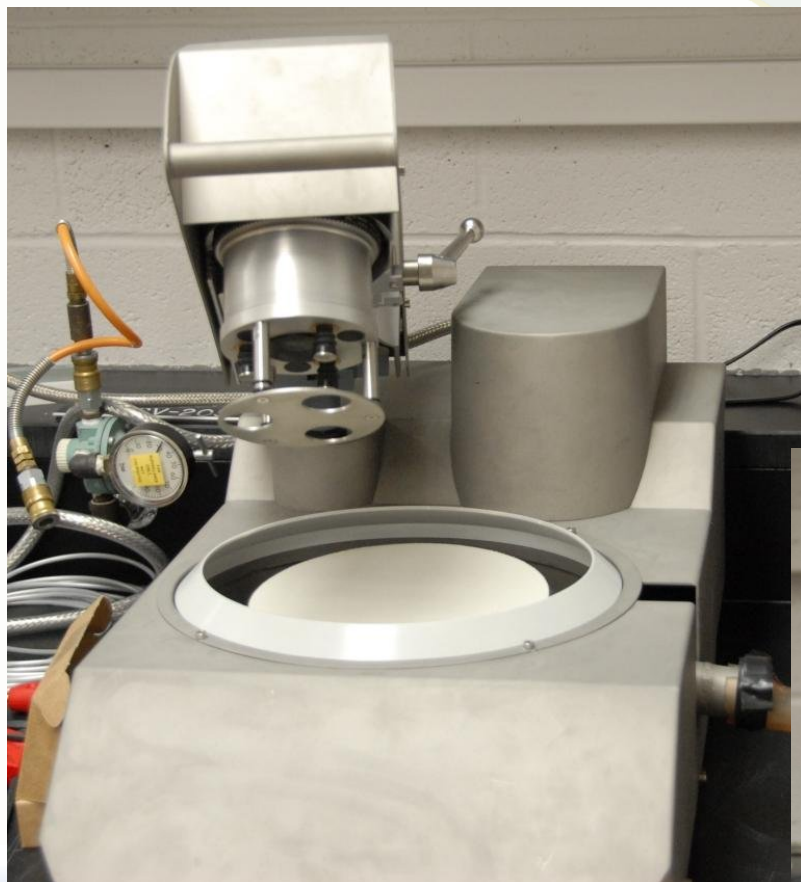


# Metallography

- Low speed saw
- Punch & die set
- Grinders/Polishers
- Met mounts 1.25" diameter
- Optical microscope up to 500x magnification



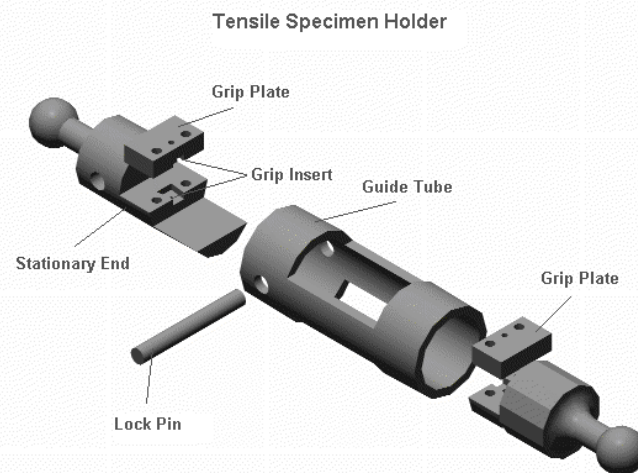
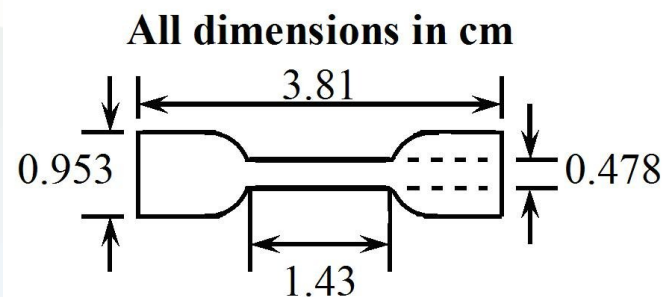
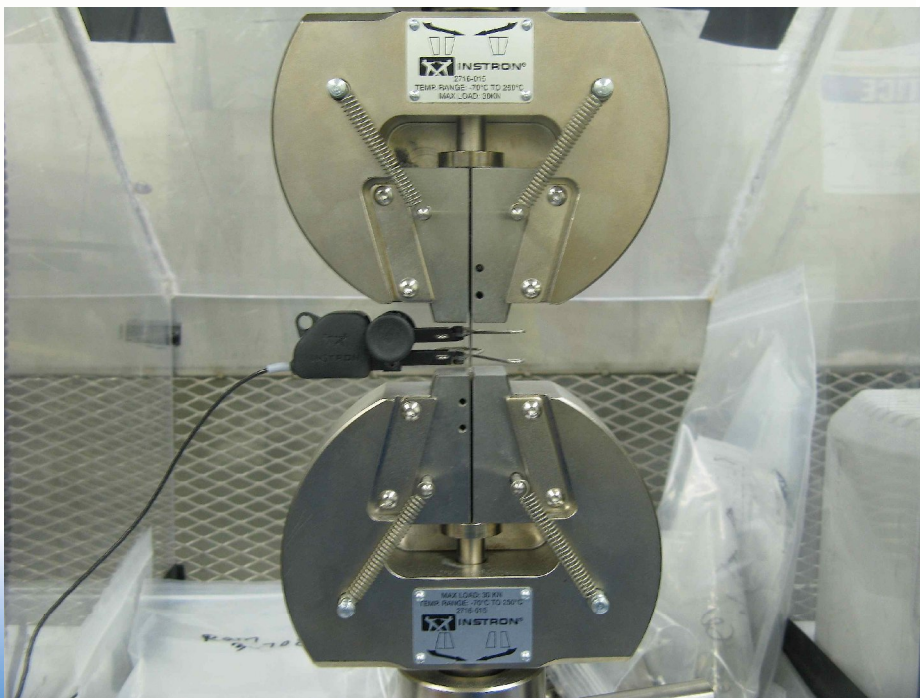
# Metallography





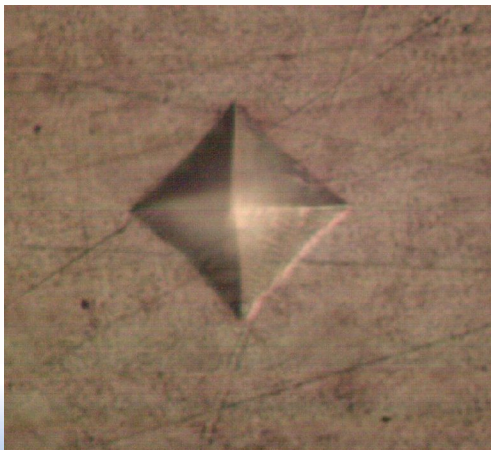
# Mechanical Testing

- Instron Load Frame
- Variable Fixtures



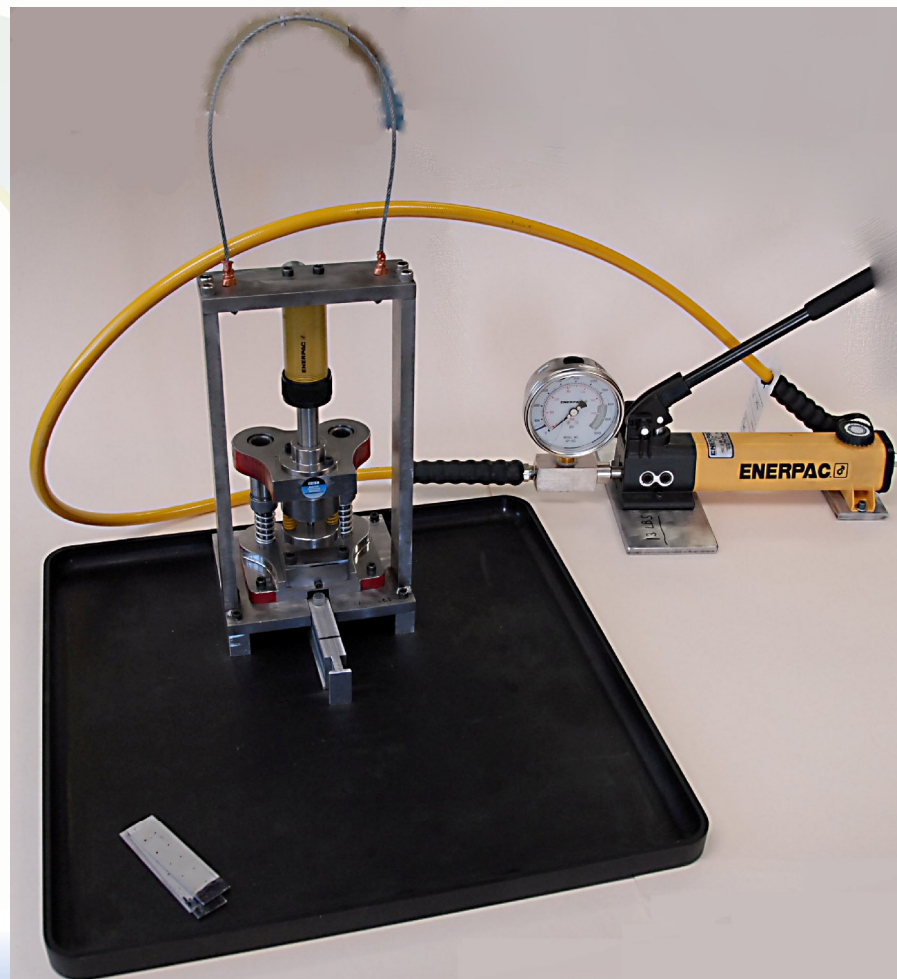
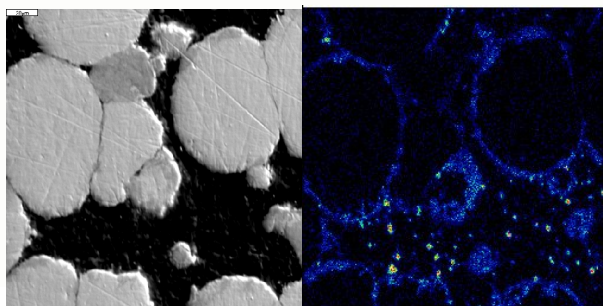
# Mechanical Testing

- Microhardness testing on round met mount samples
- 10 gf to 1000 gf with Vickers, Knoop, or dual indenters
- 10x, 50x, 100x objectives
- 2 Camera mounts



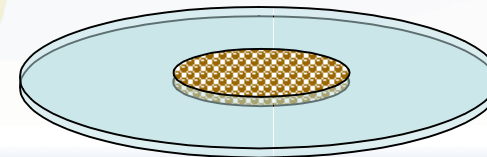
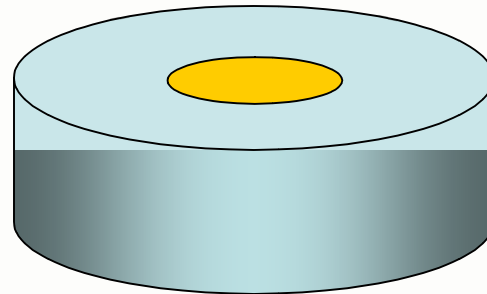
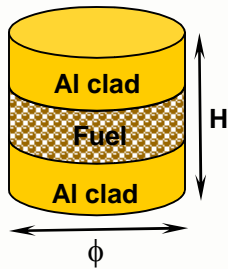
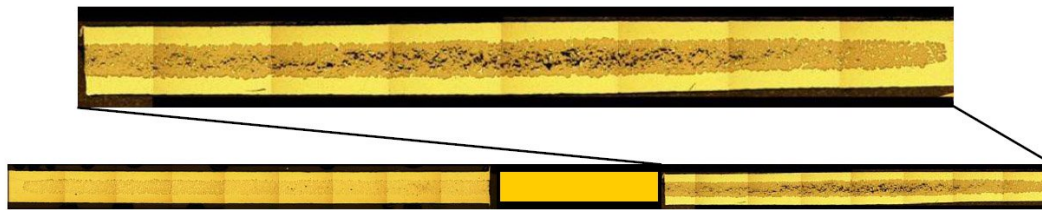
# SEM and TEM Analysis

- 1, 2, 3 or 5 mm diameter samples
- Transferred out of HFEF
- Samples prepared in Electron Microscopy Laboratory (radiation level concerns)



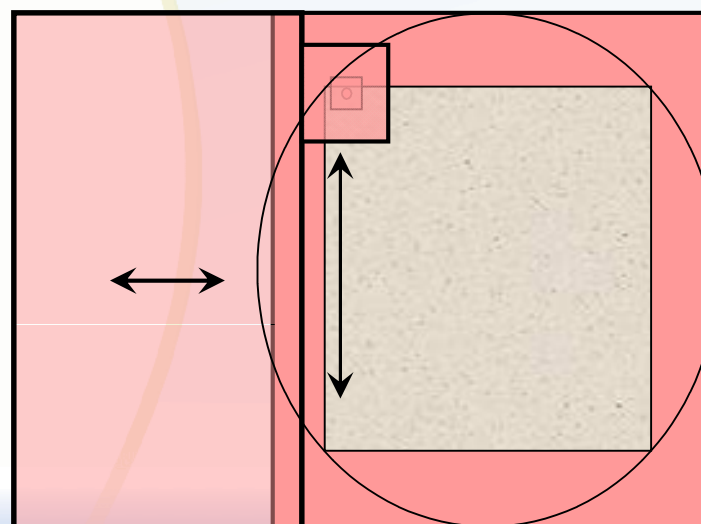
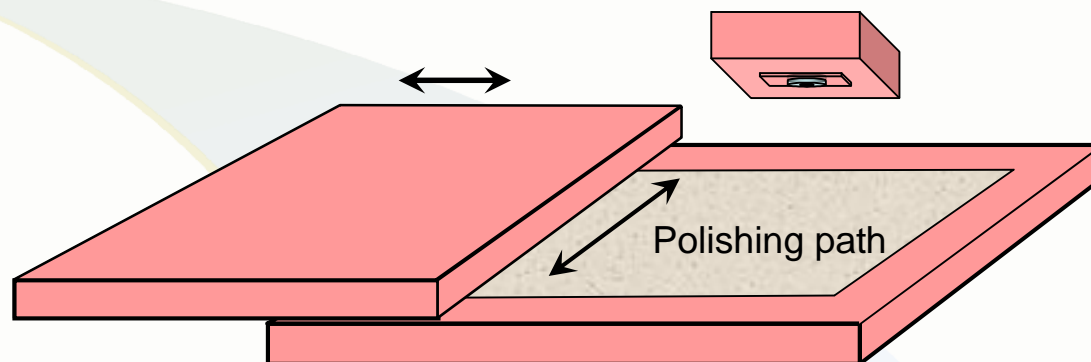
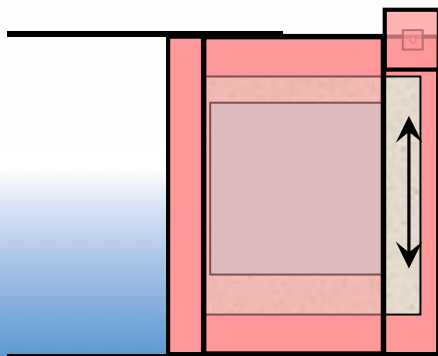
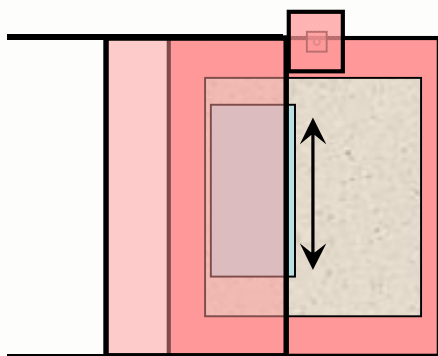
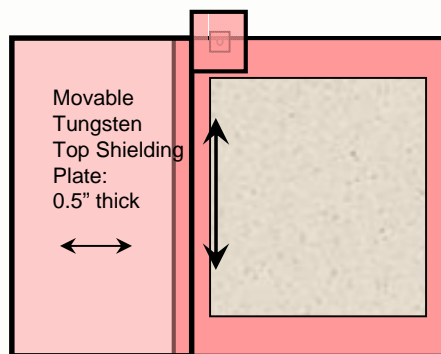


# TEM Sample Prep

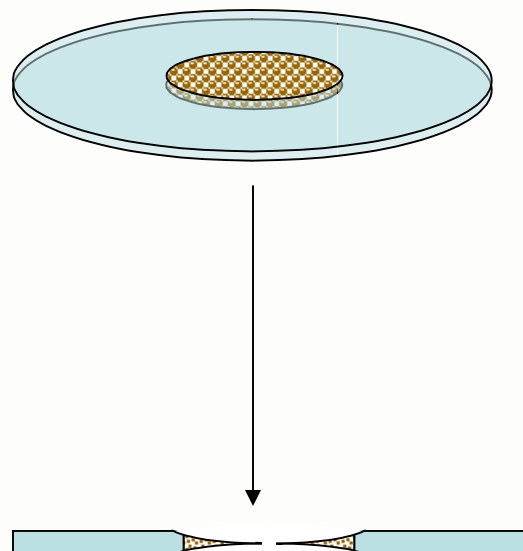


- Very small samples (1mm diameter)
- Uniquely made grinding setup
- Performed in glove box
- Use magnifying goggles for enhanced viewing

# TEM Sample Prep



# TEM Sample Prep



Slightly or w/o dimpling,  
 $t \sim 70\text{-}100\text{ }\mu\text{m}$  for fuel at center.

Use OD/ID=3.0/0.8mm **Au** grid  
( $t=50\text{ }\mu\text{m}$ ) sitting on top to prevent  
jet from attacking the epoxy bond  
and also to block light at the gap.

Electro Jet-Polishing



Jet-polishing



Ion Beam Milling (6.4hr)



Ion beam milling at 6-8 degree,  
double modulation.





# Conclusion

- Hot cell equipment requires extra time and engineering to ensure success
- Given the proper time and equipment 'anything' is possible
- Results can strongly depend on proper experiment design